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THESIS

MEASURING DAMAGE CONTROL ASSISTANT'S (DCA) DECISION-MAKING PROFICIENCY IN INTEGRATED DAMAGE CONTROL TRAINING TECHNOLOGY (IDCTT) TRAINING SCENARIOS

by

John V. Fuller

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Thesis Co-Advisor: Alice M. Crawford
Thesis Co-Advisor: Commander Frank C. Petho, MSC, USN

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This thesis developed a numeric index to evaluate the quality of decisions made by Damage Control Assistants (DCAs) while managing simulated shipboard damage control crises in support of the Total Ship Survivability (TSS) training doctrine. TSS is a doctrinal shift away from simply saving a ship after it is damaged, to both saving it and restoring its ability to fight. This doctrine imposes a new set of complex requirements on DCAs. They must comprehend, integrate, and simultaneously manage accurate, ambiguous, and frequently excessive levels of information. The Integrated Damage Control Training Technology (IDCTT) program was designed to meet these new requirements. The decision making proficiency index developed in this thesis was designed to validate the IDCTT approach. Recommendations were made to validate the index and to explore emerging technologies to enhance DCA training.

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by

John V. Fuller
Lieutenant , United States Navy
B.S., United States Naval Academy

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Author: John V. Fuller

Approved by: Alice M. Crawford, Thesis Co-Advisor

Commander Frank C. Petho, MSC, USN, Thesis Co-Advisor

David R. Whipple, Jr., Chairman
Department of Administrative Science

ABSTRACT

This thesis developed a numeric index to evaluate the quality of decisions made by Damage Control Assistants (DCAs) while managing simulated shipboard damage control crises in support of the Total Ship Survivability (TSS) training doctrine. TSS is a doctrinal shift away from simply saving a ship after it is damaged, to both saving it and restoring its ability to fight. This doctrine imposes a new set of complex requirements on DCAs. They must comprehend, integrate, and simultaneously manage accurate, ambiguous, and frequently excessive levels of information. The Integrated Damage Control Training Technology (IDCTT) program was designed to meet these new requirements. The decision making proficiency index developed in this thesis was designed to validate the IDCTT approach. Recommendations were made to validate the index and to explore emerging technologies to enhance DCA training.

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I. INTRODUCTION

Damage control decision making is an art that requires a Damage Control Assistant (DCA) to solicit, comprehend, and manage accurate information, ambiguous information, and excessive amounts information simultaneously. DCAs are currently only given the training and instruction to deal with unique and previously unknown situations at Damage Control Assistant School. Their primary opportunity to demonstrate their learned skills and to receive an evaluation of those skills is during an intense inspection called Refresher Training (REFTRA). Neither of these forums provide DCAs individualized feedback which describes the impact of their decisions on the overall performance of the ship while the crew was combating damage.

Integrated Damage Control Training Technology (IDCTT) is a research and development program which was stimulated by a doctrinal change in damage control (DC) philosophy called Total Ship Survivability (TSS). IDCTT is being designed to improve a DCA's decision making proficiency by providing specific, accurate, and immediate feedback during interactive training sessions. This training will also help bridge the gap between initial shore-based instruction and fleet inspections.

This thesis addresses a specific, but critical component of the IDCTT program; that is, the development of a quantitative measure of DCA decision making proficiency, a measure called the Fuller Decision Index (FDI). This index is unique because it focuses solely on the impact of the DCA's decision, rather than upon the effectiveness of the DC organization as a whole.

This introductory chapter discusses three key topics. First, it introduces the newly adopted Surface Warfare doctrine of Total Ship Survivability (TSS). This doctrine creates an integrated shipboard training environment in which DCAs must fuse information from different shipboard organizations before they make their decisions, and is the driving force behind both IDCTT and the FDI. Second, this chapter provides a summary on the dynamics of the cognitive aspects of decision making. Third, it summarizes five major crisis management programs which address complex decision making to provide a useful point of departure for the development of the Fuller Decision Index (FDI).

A. TOTAL SHIP SURVIVABILITY (TSS)

Of the 192 U.S. Naval warships hit by bombs, gunfire or kamikazes during WWII, 162 (or 84 percent) survived, with many continuing to fight (TSSEIP, p.iii). Recent attacks on USS STARK, USS SAMUEL B. ROBERTS, USS PRINCETON and USS TRIPOLI demonstrated that our ships, while survivable, only have a limited ability to restore their war fighting capabilities. As a result of ships' inability to mount a credible defense after being damaged, U.S. Navy surface combatant damage control training is being redirected. Doctrine is reverting from a defensive philosophy; that is, detecting and countering missile attack to avoid a hit and teaching the crew to simply save a damaged ship if hit, back to the World War II philosophy of simultaneously continuing to fight while saving the ship. This World War II philosophy is called "Total Ship Survivability" (TSS) today.

The TSS concept, while not new, is considerably more difficult to implement today because the complexity of modern warships' systems has actually made them more vulnerable to battle damage. Many of the fleet's "low mix"[1] ships were affected by budgetary constraints, and many survivability factors that are now being designed into newer platforms were not incorporated. Nonetheless, the ability of a ship to fight while damaged still depends on coordinated and rapid identification, prioritization and restoration of the systems necessary to fight the ship.

Ships will not have the ability to effectively fight while damaged if training does not emphasize the integration of command, combat systems, engineering and damage control.

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[1] "Low mix" ships refers to the concept that certain classes of ships like the Oliver Hazard Perry class Guided Missile Frigate (FFG-7), would be less capable and less survivable but could be procured in greater numbers because of lower acquisition costs.

Command personnel must have accurate information to determine the extent of the damage and the crews' ability to restore vital combat and engineering capabilities. Combat systems and engineering personnel must be trained on new procedures that enable them to reconfigure their systems, and continue to fight and maneuver the ship after it has sustained damage. Damage control personnel must know which systems clearly support ship defense, and they must communicate more accurately the location and extent of damage inflicted upon the ship to the decision makers. Even the best damage control organization will be overwhelmed if the ship is repeatedly damaged.

> TSS is a concept that pulls together three separate powerful organizations on a ship, engineering, combat systems (CS) and damage control (DC). The Navy has, in the last 50 years, been developing and refining equipment and systems to support each leg of the ship's triad. The focus has been on developing and fostering the technical development of each organization, but little has been done to bridge these three separate organizations. Specifically we have built system operation doctrines for each organization separately (engineering, CS and DC) and encouraged and fostered an attitude onboard ship to have the sailor only focus in on their own organization. This is not all bad, but when a crisis occurs, an integrated and coordinated solution may be the only way out. TSS forces us to look at the three separate shipboard organizations and in the examination expose their weaknesses for supporting the total ship (McLean, 1992).

B. DYNAMICS OF DECISION MAKING

Given the high stress environment created by TSS and the goals of IDCTT, it is necessary to understand the underlying assumptions used to develop the FDI. One major assumption is that high levels of stress will adversely affect the DCA's ability to make sound decisions. To explore that supposition, this section addresses decision making from two perspectives; (1) the human operator functioning under normal conditions and (2) the human operator functioning under stressful conditions. Each subsection will discuss four cognitive concepts involved in decision making: (a) the acquisition of information, (b) the encoding and storage of information, (c) the processing and retrieval of information and (d) the act of making a decision.

1. DECISION MAKING UNDER NORMAL CONDITIONS

Some hypothesized components of decision making include (a) *acquiring information*, (b) *encoding and storing* information (c) processing and retrieving information and (d) making the decision. These specific components of decision making are discussed to establish a normal or baseline condition in which decisions are made. Understanding how decisions are made under normal working conditions is a prerequisite for understanding how decision making quality degrades under stressful conditions.

a. ACQUIRING INFORMATION

Humans receive or gather information through their senses. Sound decisions cannot be made if relevant information is not acquired. For the purpose of this thesis and IDCTT, damage control information is obtained through the normal ship board channels available to the DCA and will be discussed in further detail in subsequent chapters.

b. *ENCODING and STORING INFORMATION*

The ability to recognize or remember pertinent information is another essential factor in decision making. Before information can be recalled, it must first be placed into memory and stored - encoded. Focused attention is crucial to encoding. A memory code can only be created if one pays attention to the desired information. Attention involves focusing awareness on a narrowed range of stimuli or events (Reed, p. 232).

Information flows through a series of three separate memory stores: a sensory store, a short term store and a long term store (Reed, p. 237). Sensory stores receive information from the eyes (iconic memory) and ears (echoic memory). Iconic memory lasts for about 100 milliseconds, while echoic memory decays slower, taking more than a second (Park, pp. 53-4). Information is retained by being transmitted to short term memory (STM). Short term memory is a limited capacity store that can maintain unrehearsed information for about 20 to 30 seconds. It stores transitory information temporarily and then almost immediately recalls it to make operational decisions. In addition to having a time constraint, STM also has a limit to the amount of information it can hold, usually seven plus or minus two bits of information (Reed, p. 240). The capacity of STM can be increased by combining a group of familiar stimuli into a larger unit or "chunk" (Reed, p. 240). It takes effort known as "rehearsal" to transfer information from short term memory to long term memory (LTM). Once in LTM information may be retained for an indefinite period. LTM involves the integration and recall of information acquired over longer periods of experience, practice, and training. This is typical of storage and recall of operational plans or emergency procedures (Park, p. 57).

c. PROCESSING and RETRIEVING INFORMATION

All relevant information must be processed before a sound conclusion can be formulated. Although not essential, pattern recognition facilitates skilled performance because it decreases the amount of unique information that must be processed. Humans can readily adapt to changing and unforeseen situations by improvising based on past experiences or intuition. With practice, humans gain experience and become more efficient at processing complex information and associating it with recognized patterns (Park, pp. 49-50).

d. MAKING THE DECISION

A decision is made when a response is chosen to fit a particular situation. Conceptually, the simplest decision is one with only two potential responses like either a yes-no or an on-off situation. For all decisions, there must be a "compare" action that evaluates the possible ramifications of choosing a particular course of action over another. When a match is found between the input conditions and the criteria for a response alternative, that response is selected and the alternatives rejected (Fleishman, p. 330).

2. DECISION MAKING UNDER STRESS

Despite human ability to receive, encode, store, process, retrieve, and use information, there are environmental factors that can adversely affect decision making. It is often difficult for DCAs to make decisions because of the complexity of the situations they encounter, and the sheer volume of information they must process. These two factors will constitute the majority of the stress in IDCTT. Stress is defined as:

> A loading, a burden, a pressure on the individual, which may come from physical or psychological sources. For practical purposes, a stressor can be considered any condition that taxes a person's resources or threatens his well being (Conlon, p. 6).

The relationship between levels of stress and human performance, in this case decision making, can be described by the form of an inverted "U" as seen in Figure 1. This function is called the Yerkes-Dodson Law. The premise of this law is that increasing the amount of stress actually drives performance efficiency up to its optimum level, after which, additional stress degrades performance. Performance is assumed to be influenced by the extent to which the stressor activates the central nervous system - arousal. The law also states that both too much and too little stress adversely impact performance, especially at the extreme regions of the inverted "U" (Conlon, p.8). An assumption of IDCTT is that high levels of stress will adversely affect DCAs when they are (a) acquiring information, (b) encoding and storing information, (c) processing and retrieving information, and (d) making decisions.

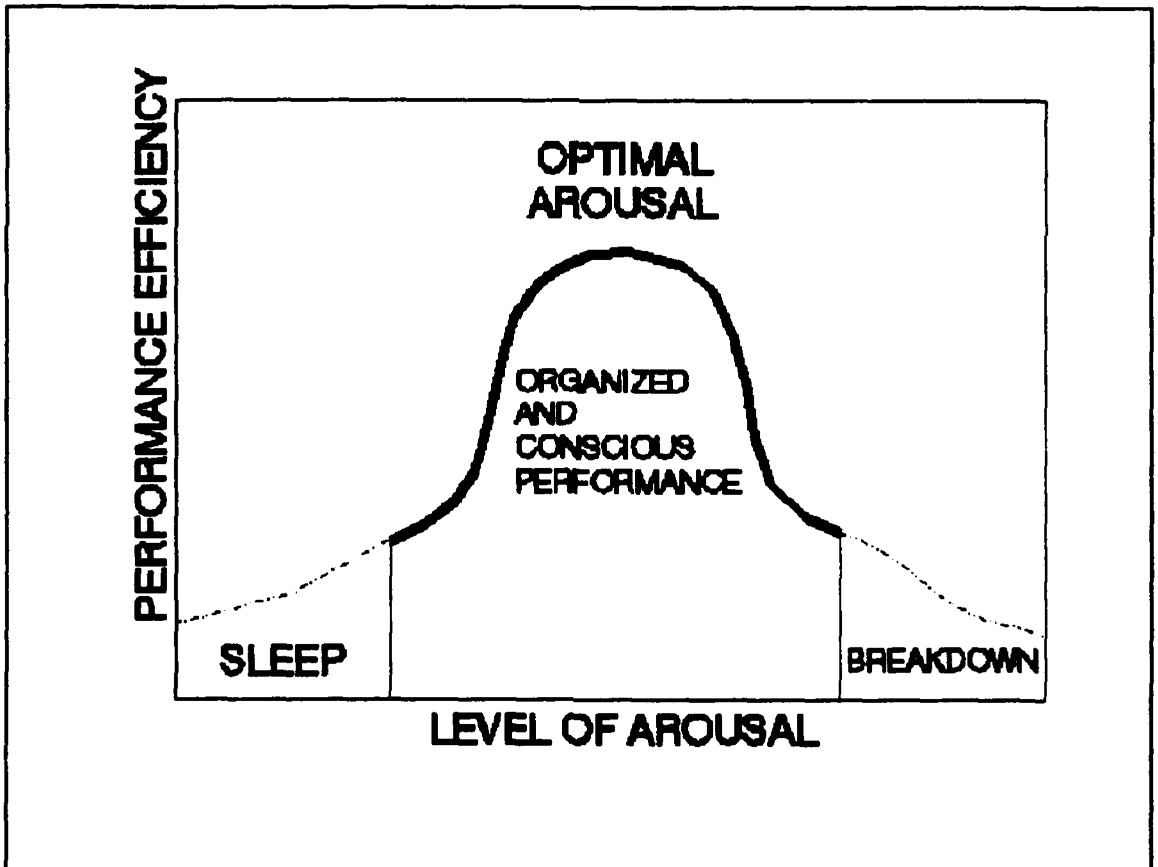

Figure 1 Yerkes-Dodson Law

a. ACQUIRING INFORMATION

The ability to acquire information may be reduced by extreme attention narrowing. Attention narrowing refers to a sharp constriction of a person's range of attention under conditions of high central system activation; that is, during states of high arousal (Conlon, p. 11). A person becomes fixated on one item while failing to recognize other equally or more important bits of information, to the detriment of the situation at large.

b. ENCODING AND STORING INFORMATION

Short term memory is adversely affected by high arousal stress. Information overload effectively blocks a person's ability to encode information into short term memory and rehearse and transfer information to long term memory (Hockey, p.291).

c. PROCESSING AND RETRIEVING INFORMATION

Processing information is not instantaneous. There is a limit on the rate of information absorption and retrieval, regardless of the clarity of the relationship between the stimulus input and response output. The delay between input and output is called processing or reaction time. Processing time may increase if information overload exceeds the decision maker's ability to process information. This limit can be reached in three ways:

First, much of the information available to an operator is either irrelevant or redundant. A novice operator will fail to recognize this and attempt to process more information than necessary. This results in overload and consequently low performance. Secondly, a task may be inherently difficult or present information at an excessive rate imposing speed stress or load stress. Thirdly, overload may occur when two or more tasks compete for an operator's attention and simultaneously present information, thereby necessitating some form of time-sharing (Park, p. 72).

d. MAKING THE DECISION

High workload induces activation. Activation is the tendency of high arousal stress to rapidly instigate action with little or no consideration for the consequences of the action. Reaction times will be quicker, but more mistakes will be made (Conlon, p.13).

3. COPING WITH STRESS

One of the most difficult topics to quantify in training is the amount of stress in an environment and its effect on an individual's ability to make decisions. Stress will be a part of IDCTT training to increase training fidelity. It will be introduced by means of information overload, high workload, noise, and inflexible time constraints. Although stress will not specifically be used as part of the evaluation in the FDI, it is an essential tool for improving the DCA's ability to cope with stress and make decisions.

High levels of workload cause human errors. Human errors can be defined as a failure on the part of the human to act) within specified limits of accuracy, sequence or time (Park, p. 6). The ability to cope with stress will increase the likelihood of making proper decisions and decrease the likelihood of errors. Coping may be evaluated as a function of the ratio between mental demands and capacity. The more an individual's capacity exceeds the demands, the higher the probability of efficient future coping efforts. Conversely, the more the demands on an individual exceed the capacity to cope with stress, the more likely that person will be less able to withstand additional stress after a period of experienced inefficiency.

Behavior in stressful situations is therefore directed towards the regulation of the demand/capacity ratio. The ratio can be improved (a) by raising an individual's capacity (for example, by acquiring a new skill, increasing effort, or <u>improving training</u>) or (b) by lowering demands (for example, by reducing uncertainty through information aids) (Hockey, p. 326). Training needs to be developed to help the decision maker balance the demand/capacity ratio. The concept of Total Ship Survivability has increased the demand on the DCA. The concept of IDCTT evolved because the environment created by TSS demands that either the DCAs become better decision makers, or they fail.

C. DECISION MAKING SUPPORT PROGRAMS

While there are few tasks that have requirements identical to a DCA in a TSS environment, there are several programs that are designed to train for and evaluate decision making during critical situations. This section reviews five such programs: (1) Headquarters Effectiveness Assessment Tool, (2) Telecommunication Emergency Decision Support System, (3) Tactical Decision Making Under Stress, (4) Integrated Survivability Management System, and (5) Operational Sequencing System. This analysis focuses on each programs' decision making assessment components and methodologies which may provide insight into the development of the FDI.

1. HEADQUARTERS EFFECTIVENESS ASSESSMENT TOOL (HEAT)

> HEAT is a set of consistent procedures which measure the effectiveness of a military headquarters or command center. HEAT supports quantitative, objective and reproducible assessment of both the quality of the process by which information is used by the commander and his staff in decision making (and of the systems which support the process), and the overall effectiveness of the decisions made and their implementation (HEAT User's Manual, 1985, p. 1-1).

HEAT views a headquarters as an adaptive control system which, like a DCA, seeks to impact the environment by means of the plans or orders it issues. (HEAT User's Manual, 1985, p. 1-1) The underlying principal of HEAT assumes that if headquarters issue more effective orders, they require little to no modification over time, while issuing inefficient orders either requires constant revision or a countermand and re-issuance. HEAT uses a four step process to quantify and therefor^ validate its theory of headquarters effectiveness.

First, HEAT attempts to quantify the output of a headquarters by comparing the actual time each plan remains unchanged against its expected unchanged time or life span to yield a "plan length." Second, HEAT addresses the percentage of the time the decision making process produces excellent, adequate or inadequate plans. This approach accounts for the fact that headquarters often operate under conditions of uncertainty by measuring the frequency appropriate directions are given (Hardee, 1985, p. 56). Third, HEAT considers the information input necessary before a headquarters issues orders by examining the process of command and control, which was reduced to six basic functions:

- Monitoring what is happening in the environment;
- Understanding the characteristics of current or emerging situations that have tactical or strategic significance;
- Generating options;
- Predicting the impact of each option on future situations (sensitivity analysis);
- Deciding which option or combination of options to take; and
- Directing the execution of those decisions (HEAT User's Manual, 1985 p. 1-4).

Finally, HEAT considers communications that: (1) inform superiors, subordinate and coordinate headquarters, (2) query units about incomplete information, and (3) respond to queries from superiors, subordinates and coordinate headquarters; all factors that effect headquarters' operations (HEAT User's Manual, 1985 p. 1-5).

The communications required for command and control in a headquarters are very similar to those of a DCA during a damage control evolution. HEAT's methodology provides valuable insight for establishing objectives that examine the use of information within an organization before a decision is made. HEAT, however, is no longer used because its evaluation paradigms were too rigid and too complex. HEAT analysis is impossible unless the evaluator separates the functions of operations planning and order issuance within the headquarters being evaluated.

2. TELECOMMUNICATIONS EMERGENCY DECISION SUPPORT SYSTEM (TEDSS) AND EXERCISE PROCESSOR FOR AN INTERACTIVE SIMULATION OF A DECISION ENVIRONMENT (EPISODE)

TEDSS is a computer-based tool developed to support the Office of the Manager, National Communications System, for the management of national telecommunications resources in times of national emergency. TEDSS training parallels another area that is critical a DCA's job; resource management in crisis situations. TEDSS provides managers the capability to access, display, and utilize their resources, requirements, and communications data to manage the restoration and reconstitution of communication assets (TEDSS version 7.0 Tutorial).

EPISODE, which is also computer-based, was developed specifically to support TEDSS.

> It is designed to provide the exercise control and player communications simulation functions, and to provide for non-intrusive data collection for post event analysis and evaluation (EPISODE presentation, 1992 p. F-2).

While EPISODE is designed to provide individual and group TEDSS user training, it can be adapted to evaluate any type of system involving different communicating nodes like those in the damage control organization (EPISODE presentation, 1992 p. F-3).

EPISODE uses four software programs: Manager, Node, Central and Analysis. These programs coordinate through a common system clock, executing independently to serve as an exercise support tool with the abilities to develop realistic, stressful, interactive training scenarics that records the performance of a decision maker in real-time. EPISODE attempts to record the unique effects an individual's decisions have on restoring communications systems during a crisis. The statistics calculated by EPISODE to evaluate the decision maker are the mean and standard deviations of five parameters: (1) message creation time, (2), message send time, (3), delay prior to transmission time (4), backlog time and (5) respond time (EPISODE Users Guide, pp. 6-8).

By only using five simple statistics to measure performance, the TEDSS/EPISODE post-exercise evaluation provides the user no real insight into the unique effect each decision had on resource management or system restoration. A lesson learned from reviewing TEDSS/EPISODE is that IDCTT must clearly define decision maker behavioral requirements and provide meaningful feedback and evaluation that will help improve future performance.

3. TACTICAL DECISION MAKING UNDER STRESS (TADMUS)

Decision makers in modern warfare are faced with situations characterized by rapidly unfolding events, multiple plausible hypothesis, high levels of information ambiguity, severe time pressure, and severe (often catastrophic) consequences for errors. USS VINCENNES shooting down an Iranian Airbus A300, Iran Air Flight 655 in 1988 was the impetus for TADMUS. The Navy wanted a research program to explore avenues that better prepare tactical decision makers for the complexities of Anti-Air Warfare (AAW). The resulting program, TADMUS, which continues in its development, is intended to aid decision making in situations that are stressful, rather than to reduce the stress (TADMUS Program Study, p. 1).

> The objective of the TADMUS program is to apply recent developments in decision theory, individual and team training, and information display to the problem of enhancing tactical decision quality under conditions of stress (TADMUS Program Study, p. 2).

TADMUS developed concepts that were instrumental for the development of the FDI. These concepts delineated critical guidelines, which closely parallel the requirements IDCTT, for thoroughly evaluating DCA performance durinj realistic scenario-driven training. While IDCTT examines the role of the DCA in support of TSS and TADMUS focuses exclusively on combat systems team performance, the programmatic similarities between TADMUS and IDCTT are clearly articulated by the TADMUS program deqign. TADMUS concepts developed a framework in which performance defi ition and measurement are quantified by creating: (a) specific definitions and measurement goals, (b) a scripted (AAW) scenario and (c) the concept of quantified measures (TADMUS Program Study, p. 1).

a. STATEMENTS OF DEFINITIONS AND MEASUREMENT GOALS

Defining and measuring performance required methodology that reduced performance evaluation into its fundamental components. T' e four components or actions derived by TADMUS, (1) understand the decision, (2) establish a laboratory test/delivery system, (3) develop Measures of Effectiveness (MOEs), and (4) establish baseline decision making performance are describe below.

(1) UNDERSTAND THE DECISION TASK

Analyze the AAW process to understand the problems faced by AAW decision makers to help them (TADMUS Program Study, p. 2).

(2) ESTABLISH LABORATORY TEST/DELIVERY SYSTEM

Establish an operational test system that can present the full scenario while recording all events in the context of established Performance Standards, Measures of Performance (MOPs) and Measures of Effectiveness (MOEs) for future analysis (TADMUS Program Study, p. 2).

(3) DEVELOP MOEs

Develop MOEs that include both measures of decision making processes (quality of reasoning, team coordination etc.) and decision making outcomes (decision accuracy, consequences, etc.) (TADMUS Program Study, p. 2).

(4) ESTABLISH BASELINE DECISION MAKING PERFORMANCE

Conduct experiments using Navy Combat Information Center (CIC) teams to provide a baseline performance against which later experiments and variations can be contrasted. This will help establish how well a trained CIC team is expected to perform in various types of scenarios (TADMUS Program Study, p. 2).

b. AAW SCENARIO

The scenario is composed of background information, mission assignment and a sequence of nine decision situations, or vignettes. The sum of the nine vignettes constitutes a game. Three major uncertainties occur in the vignettes: Rules of Engagement interpretation, contact identification and contact intent (TADMUS Program Study, p. 3). Unlike IDCTT scenarios, the TADMUS vignettes were designed so that a decision in one vignette would not influence decisions in later vignettes.

c. CONCEPT OF QUANTIFIED MEASURES

TADMUS uses a comparative method for quantifying the decision maker's behavior. A baseline is determined by a

> . . . team of very experienced officers who assign numerical relative importance in the context of the tactical situation to the various decision opportunities and further assign numerical relative values of the tactical outcomes to the various possible decisions themselves that can be taken at each opportunity. Importance times value yields a tactical worth for each of the various decisions, including assessments and act-choices. This (comprehensive) list of worths provides numerical scores for each decision made by the DM (decision maker). The intent is not to establish what decisions are "right", but what decisions are typical of trained, experienced officers (TADMUS Program Study, p. 4).

The resulting Performance Standards describe quantitatively what action should be taken by an experienced CIC team under normal combat stress. MOPs describe quantitatively what action actually was taken. MOEs relate MOPs to Performance Standards, that is, effectiveness is shown by contrasting actual performance to performance targeted (TADMUS Program Study, p. 4).

d. SUMMARY

The TADMUS concept for quantifying CIC team decision making performance is both logical and innovative. These concepts are easily transferred to the tasks and functions of a DC organization. Unlike IDCTT, TADMUS does not try to quantify the effect a single team member has on the overall performance of the team. This artificiality designed into TADMUS appears to be a flaw in training ideology because of the assumption that critical decisions are made democratically. Even though many situations in CIC are command by negation, the commanding officer (CO), and in his absence the Tactical Action Officer (TAO), have the ultimate burden of making the key decisions. Individuals should receive training that can record and evaluate their unique impact on their team's performance.

4. INTEGRATED SURVIVABILITY MANAGEMENT SYSTEM (ISMS)

The Naval Sea Systems Command (NAVSEA) is implementing a comprehensive program in which all aspects of TSS are being considered; that is, systems engineering, naval architecture, command and control systems, ship's bills[2], manning, and training. Moreover, because of the complexities of TSS, the role new technology can play in helping DCAs process the stunning array of information to arrive at sound conclusions, especially under conditions of extreme workload, is being explored.

a. DAMAGE CONTROL MANAGEMENT

Damage control (DC) management consists of acquiring, processing and displaying the necessary information

[2] Ship's bills are documents that prescribe the jobs, billets and responsibilities of the crew during specific evolutions.

to support the command, control and communications of the damage control battle organization while it is under casualty conditions (The ISMS Ship Board..., p. 3). Damage control decision making has always been difficult due to the volume of information that must be processed. Information retrieval and display depend on communications from a messenger or sound powered phone talker and the use of grease pencils to position casualty status symbols on laminated DC diagrams.

The delayed gathering and transmission of information on the type and location of damage and the complexity of coordinating repair party actions with other ship activities created a need for more efficient and coordinated DC management. A system that could display real-time DC information would increase the efficiency with which a casualty could be controlled. Even with this type of system, managing a DC problem would still depend on the ability of decision makers to translate available information into a comprehensive picture, prioritize the casualties and order actions that return the ship to the highest possible level of readiness.

b. ISMS PROGRAM DESIGN

In response to the growing need for more coordinated damage control command, control and communications (C^3), NAVSEA is developing a computerized DC information acquisition, processing, and display program called Integrated

Survivability Management System (ISMS).

> ISMS will provide correlated information, by means of computer generated decision aids, to the battle organization upon which to make real time decisions concerning properly focusing damage control resources to effectively engage and contain damage; present the same decision making picture to all stations in the battle organization; and enable battle organization decision makers to issue orders and execute control actions (Combat System Battle Damage..., p. ES-1).

The goal of ISMS is to significantly enhance the DC process in several areas: (1) determining the type and location of weapon effect, (2) communicating this information to decision stations, (3) displaying the information, (4) integrating the information with the ongoing activities, (5) developing plans of action, (6) initiating commands, and (7) executing the commands by merging traditional survivability efforts with improved communications and computer support. This accelerated process should minimize the spread of damage while maximizing the remaining mission capability of the ship (The ISMS Ship Board..., p. 1).

Displays envisioned for ISMS stations are:

(1) SUMMARY DAMAGE DISPLAY

The damage display includes the same information given by damage control diagrams with all damage plotted.

(2) SPECIFIC SYSTEM DAMAGE DISPLAY

The system would provide the ability to "zoom" into specific systems showing schematics with the location of the components and equipment effected. It will reduce "clutter" by layering details as part of the "zoom" feature, while also providing, on demand, suggested reconfiguration for specific damage.

(3) CONTROL

The system would display equipment status including the availability of remote operation from the ISMS station.

(4) ROUTING INFORMATION

It would present preplanned routes stored in the database for rapid movement of personnel and material for routine and damage conditions. Post damage route modification will also be available.

(5) STABILITY

It would supply information for maneuvering, predicted list and trim for various counterflooding options and predicted effects of continued flooding on stability as well as stability curves for actual loading and damaged conditions (The ISMS Ship Board..., pp. 18-23).

ISMS and IDCTT deal with different aspects of the same problem - improving the performance of the DCA. IDCTT is being developed to enhance the ability of the DCA to process all inputs and make better decisions, while ISMS is being developed to improve the information being presented to the DCA. The next and final program examined supports TSS by integrating and simplifying the presentation of vital ships systems.

5. OPERATIONAL SEQUENCING SYSTEM (OSS)

The first TSS exercise conducted on USS PRINCETON exposed a major obstacle to the ability to fight while hurt. There is discontinuity over departmental responsibility that is exacerbated by documentation oversights for the chilled water system, which keeps the U.S. Navy's most electronically sophisticated warships operational. The criticality of this situation was highlighted during the actual mine damage to PRINCETON during the Persian Gulf War. PRINCETON was without chilled water for an extended period of time after she hit a mine. Chilled water is designated a vital system because of its essential support of weapons, surveillance and communication systems operations. The chilled water system removes the heat generated by electronic equipment. An interruption to the chilled water supply, even for a few minutes, may cause some systems to shut down from high temperature or even fail (NWP 62-1 (Rev.C), pp. 1-11).

The chilled water system design on PRINCETON lacked the flexibility to sustain and then quickly recover from battle damage. It also lacked integrated documentation[3] that

[3] The responsibility for chilled water system is divided between the supplier (engineering) and the user (combat systems) during normal operations. The main deck is normally the demarkation for each department's area of responsibility. The DCA is responsible for all ship's piping systems and therefore responsible

would support rapid reconfiguration. Individual valves were designated differently in Engineering Operational Sequencing System (EOSS), Combat Systems Operational Sequencing System (CSOSS)[4], and on the damage control plates[5], with no means of cross referencing valve labels. Also, some system changes were not documented. These shortcomings made it extremely difficult for engineering, combat systems and damage control personnel to coordinate their restoration efforts.

The Operation Sequencing System (OSS) was developed as a result of the difficulties the PRINCETON had restoring her chilled water. It is designed to prevent future chilled water restoration difficulties. OSS uses the standard DC plate format by displaying the chilled water system within an orthogonal view of the ship. Since the chilled water system can be divided into several autonomous loops, OSS displays them in separate colors. OSS also graphically presents information on chilled water's supply, valves labels, piping runs, loop cross connects, the systems that it supports, and

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for coordinating the activities of the crew for restoring chilled water piping during a casualty. All three activities have different labeling systems for their respective area of responsibility.

[4] EOSS and CSOSS provide exact procedures for aligning and operating specific systems and pieces of equipment. They also provide emergency or casualty procedures that are designed to save lives and to protect the machinery and systems involved.

[5] A diagram that shows the subdivisions of the ship and its systems. There are specific plates to show each of the major piping systems as well as plates showing only subdivisions.

its return piping. The OSS diagram has a color coded valve cross reference legend that allows the user to identify specific valves using CSOSS, EOSS or damage control diagrams.

During normal operating conditions or in crisis situations, OSS simplifies the manual process of identifying alternate paths necessary for reconfiguration or restoration of the chilled water system. Although the system diagram provides the decision maker with more than enough information to quickly isolate a casualty, OSS has also been computerized. The OSS data base contains the same information presented on the diagram, as well as the ability to analyze chilled water alignment[6]. The system can, on demand, prescribe specific valves that need to be actuated to segregate specific chilled water loops or related systems during both normal and casualty situations. This vital reconfiguration information would provide training before and facilitate quicker decision making and quicker restoration of the chilled water system in the event of a casualty (Budai, 1992).

> OSS is not approved by the Navy and is not currently implemented except as a concept. OSS is really an improved DC plate, with the addition of software that can be used as a training and familiarization aide for the chilled water system. I think the DC chilled water plate and others (high pressure air, firemain etc) can be

[6] OSS has been programmed to accept valid valve alignment. If an individual wants to close a valve to operating machinery without providing a second source of chilled water, the computer prevents the closure. It has been programmed to accept only proper configurations of the system as prescribed by CSOSS and EOSS. It also has the ability to be reconfigured during a casualty situation.

radically improved and integrated with selected CSOSS and EOSS information and then inserted into the combat systems, engineering and DC organizations to help facilitate each organization working from the same frame of reference when coordination is critical" (M^cLean, 1992).

D. SUMMARY

Understanding the basic dynamics of decision making and the daunting environment created by the need for TSS, makes it clear that the task of training DCAs has become more important, and more difficult. Although not inclusive, this research derived seven key training and evaluation concepts from the projects reviewed for IDCTT and specifically the FDI:

- Develop concise definitions for specific performance standards, measures of performance (MOP) and measures of effectiveness (MOE);
- Evaluate theories and models for determining how training on information management could best support the decision maker;
- Develop a better understanding of the specific role of the DCA. It will improve training on systems integration and personnel coordination during crisis situations;
- Understand the criticality of defining training objectives that will improve future decision making in an operational environment;
- Develop realistic, stressful training scenarios;
- Ensure task-specific evaluation and feedback are linked to the precise time an event occurred during a scenario; and
- Adopt the concept that the evaluative process is not to establish which decisions are "perfect", but which decisions are typical of well trained personnel.

II. TOOLS FOR DEVELOPING IDCTT

Chief of Naval Operations (CNO) mandated that training be conducted for personnel who,

> . . . because of their battle organization and administrative duties, require additional ship survivability and damage control training primarily in the areas of battle and emergency preparation; battle and emergency decision making; conflagration control; assessment of residual capabilities after battle damage; damage containment priorities; equipment and vital system restoration priority setting in support of maintaining or restoring warfighting capability after damage; vital systems capabilities and reconfiguration decision making to support essential ship, mission and damage control capabilities. Level IV training is to be conducted both ashore and on board ship through drills and exercises. Level IV training includes instruction in conflagration, threat weapons effects to the ship for areas of ship deployment and the operation, management, reconfiguration and administration of the battle organization as it impacts ship survivability. This level of training will also include instruction in inspection and battle damage investigation procedures to be employed on shipboard vital systems and in procedures to properly conduct shipboard survivability drills/training (OPNAVINST 3541.1D, p. 3).

In support of IDCTT and in compliance with CNO mandated training, this chapter examines (a) Interactive Courseware (ICW); the media selected to deliver IDCTT, (b) the Computer Aided Medical Information System (CAMIS); the format selected to deliver IDCTT, (c) the Battle Damage Estimator (BDE); the program that generates realistic weapon's effect data for IDCTT and (d) basic damage control theory; the component that provides structure for IDCTT.

A. INTERACTIVE COMPUTER TECHNOLOGY

Dynamic interactive training is proving to be an effective instructional method. It has the potential to satisfy the training requirements mandated by both the CNO and TSS. A readily available source for this type of training is interactive courseware (ICW). ICW is a global term tha incorporates computer-based instruction (CBI), computer managed instruction (CMI) and other interactive media. CBI provides an interactive learning experience by providing a stimulus that requires a user's response, and then provides feedback to the user's input. CMI is the subsystem of ICW that plans, administers, monitors, allocates instructional resources, and provides reports on the student performance.

ICW can be used to teach facts, concepts, principles, rules, procedures, and psychomotor skills (GE Aerospace, p. 2). It also allows practice of dangerous procedures without the risk of injury of damage. Finally, when compared to traditional instruction, ICW programs have been shown to reduce student instructional time by about 30 percent, increase student achievement by 0.40-0.50 standard deviation units, and cost less than half as much (Fletcher, 1992 p. S-2).

A sophisticated form of ICW instruction, interactive videodisc (IVD), requires a student to participate actively in a training environment that provides rapid, random access to a large, inexpensively stored data base of video quality images and sequences. For the purpose of this thesis, IVD will be referred to as ICW.

> It is a videodisc system in which the videodisc player is interfaced to an external computer. The videodisc player acts as a computer peripheral with its functions under the computer's control (Fletcher 1990, p. I-5).

The 1989 Department of Defense Appropriations Bill required the Department of Defense (DoD) to conduct a thorough analysis of the use of ICW technology as it pertains to effectiveness, cost effectiveness, time on task, retention, and overall applicability to current and future DoD training and education requirements. Forty-seven studies were reviewed. A synopsis of the ICW technology findings follows.

<u>ICW EFFECTIVENESS</u>

- Used successfully to teach;
- More effective than conventional instruction (classroom,military training and higher education);
- Equally effective for both knowledge and performance outcomes;
- The more the interactive features of ICW technology were used, the more effective the resulting training;
- Directed, tutorial approaches were more effective than stand-alone simulation in ICW instruction;
- Resulted in less varied student performance;

<u>ICW COST</u>

- Less costly than conventional instruction;

<u>ICW COST EFFECTIVENESS</u>

- More cost effective than conventional instruction;

<u>TIME ON TASK</u>

- May increase time on task (more time for training on more important tasks);

RETENTION

- Seems unlikely to effect retention (suggesting the value of ICW lies in improving efficiency not retention);

CONCLUSIONS

- ICW is more effective and less costly than conventional instruction;
- ICW instruction can have a significant positive impact on military training and education;
- More needs to be learned about how ICW instruction should be designed and utilized; and
- ICW instruction should be routinely considered and used in military training and education (Fletcher, 1990, pp. S1-S5).

B. COMPUTER AIDED MEDICAL INFORMATION SYSTEM (CAMIS)

CAMIS is not a single program, but a series of ICW productions that are used as interactive multimedia training programs for the medical community (Omerod, 1992). Some of the CAMIS productions are stressful, real-time scenarios that test emergency and clinical procedures. The methodology used for creating these training scenarios is being incorporated into the development of IDCTT because of the parallel functions of human physiology and ship design and similarities between decisions made during triage and damage control procedures. Both the doctor and the DCA have priority actions that must be taken immediately if the "patient" is going to survive. Supplemental actions may be taken after the "patient's" condition has been stabilized. To make a correct diagnosis and administer the proper treatment, the CAMIS user must recognize the pertinent information from all the clues provided, no matter how subtle, and/or take actions necessary to acquire additional information.

1. CAMIS METHODOLOGY

Like the procedure for determining the Performance Standards for TADMUS, CAMIS productions use the performance of experts as the baseline for evaluating students.

> We describe each situation as a "problem space" with several alternatives, death, partial recovery and full recovery. We establish an original path to success when the scenario is written. Next, the experts go through the scenario to determine their actions or unique paths. The results are tallied and analyzed. A pattern normally evolves in which each expert performed a particular task in the same order and at nearly the same time. This helps determine items of priority that will later become teaching points. In some cases an expert may have come up with an improved technique or path to navigate through the problem space that no one else considered. After all that information has been compiled and the scenario reviewed, the experts evaluate the frequency, order and time that actions were taken. They make comments about the decision points or nodes that created the successful path, and amended it to include improvements. This process validates an expert defined path to success (Allely, 1992).

The technology used for CAMIS records every input from the student for immediate feedback and subsequent evaluation. The first and most obvious feedback or measure of a student's performance is if the patient lives or dies. How the student went about exiting the problem space is evaluated according to the percentage of student decisions that concur with the experts, the absolute time it took to navigate out of the problem space and the time difference between the student and expert. It is important to note that this process is not used to establish what decisions are "right," but what decisions are typical of well trained personnel.

2. CAMIS VALIDATION

Numerous studies (Fletcher, 1990, pp. S1-S5) have found that ICW improves the quality of training, and CAMIS is no exception. The U.S. Naval Health Sciences Education and Training Command validated three CAMIS programs developed for the Operating Room Technician (ORT) School at the National Naval Medical Center in Bethesda, Maryland: *ORT Mediquiz--Surgical Instrumentation, Principles of Aseptic Technique*, and *Mock Surgery* (Interactive Multimedia Courseware Validation Report, p. i). The test scores of the 24 student validation class were compared to the historical test scores of classes not using CAMIS as part of their instruction. The findings of the report are summarized below.

a. SURGICAL INSTRUMENTATION

Surgical instrumentation is taught in four classrooms sessions. The first of the four sessions introduces the general structure, types, and terminology of instruments, their care and handling, and one group of specific instruments. The other three sessions teach only groups of instruments. The first lesson was taught using the traditional lecture method because all of the material was not present in *ORT Mediquiz--Surgical Instrumentation*. The remaining lessons were taught using CAMIS either to support a classroom presentation or for individual study without lecture (Interactive Multimedia Courseware Validation Report, p. i).

There are five tests on instrumentation. All students received the same type of instruction before the first test and the mean test score of the validation class was equal to the historical mean score of other classes. For the other four tests on material taught with CAMIS, the validation class's mean test scores were 97 percent, 98 percent, 99 percent, and 98 percent with an overall mean of 98 percent. Ninety-six percent of the class received grades of "A". This is a "substantial"[7] increase over the scores of the previous classes who averaged mean scores of 95 percent, 95 percent, 96 percent, and 94 percent, with total mean score of 95 percent. Only 76 percent of the previous classes received the grade of

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[7] The table shown below highlights the significance of these results; as the mean score (in percentage) increased in the validation class, the variability associated with these scores decreased. These systematic trends point to the enhanced learning effect attributable to the interactive media format.

TEST	# OF ITEMS	VALIDATION CLASS MEAN%	STANDARD DEVIATION	COMPARISON CLASS MEAN%	STANDARD DEVIATION
I	56	92	4.88	91	5.33
II	50	97	4.86	95	4.75
III	75	98	1.75	95	6.10
IV	100	99	1.15	96	5.60
FINAL	100	98	1.86	94	6.11

Source: Interactive Multimedia Courseware Validation Report

"A" (Interactive Multimedia Courseware Validation Report, p. ii).

Data based on surveys and interviews with the students and instructors revealed that:

- Videodisc images of the instruments were preferred over slides;
- CAMIS was effective when used for self-study, freeing instructor time for other training matters; and
- With fewer low scores on the tests, remediation and other follow-up tasks could be reduced (Interactive Multimedia Courseware Validation Report, p. ii).

b. PRINCIPLES OF ASEPTIC TECHNIQUE

Aseptic technique primarily deals with preparing a sterilized environment for the operating room, its equipment, and personnel before an operation. The *Aseptic Technique* ICW instruction was presented to the validation students in a classroom by an instructor, after which the students immediately used the exercise portion of the courseware. At their leisure, they used the ICW for review and test preparation during the week before the exam (Interactive Multimedia Courseware Validation Report, p. ii).

The students were tested using the ICW test on a random selection of 25 still and motion video items from a 48 item pool. Forty-two percent of the class achieved a perfect score and 92 percent achieved a score of 92 percent or higher. Instructors considered the ICW testing strategy superior to the previous strategy because it required the student to visually identify breaks in aseptic technique instead of writing out each of the principles verbatim. The ICW format is especially desirable because one of the primary purposes of the *Aseptic Technique* instruction is to prepare the students for the live *Mock Surgery* test (Interactive Multimedia Courseware Validation Report, p. iii).

c. MOCK SURGERY

The student survey indicated that each validation student used the ICW an average of seven times, for an average total duration of 7.5 hours before the test. The *Mock Surgery* test requires a student to perform the role of either a scrub or circulator[8] during a simulated surgical procedure. The ICW developed for mock surgery included a 45 minute simulation of an appendectomy; a five minute *bonus round exercise* simulating the use of instruments in a surgical setting, and if necessary, instructor access into the simulated events for instruction and remediation purposes (Interactive Multimedia Courseware Validation Report, p. 26).

The comparison class, which had no exposure to the *Mock Surgery* ICW, had an overall passing rate of 52 percent. The class that was informally exposed to the draft ICW during a "Beta Test" (not in formal instructional settings) had an overall passing rate of 79 percent. The validation class,

[8] Scrubs ensure the sterility of individuals entering the operating room and circulators ensure the sterility of the equipment used in the operating room.

which used the ICW formally in its instruction, had a passing rate of 98 percent (Interactive Multimedia Courseware Validation Report, p. iv).

3. SUMMARY

The validation report makes a strong argument in favor of using ICW during formal instruction as well as allowing the students access to it for individual study. ICW decreased instruction time while improving the students' ability to understand information and apply it as knowledge to specific skills. The enthusiasm of IDCTT's developers for the CAMIS format stems from the conceptual parallels between damage control and certain medical procedures. Even the three productions developed for ORT, *ORT Mediquiz--Surgical Instrumentation, Principles of Aseptic Technique*, and *Mock Surgery* can be described in damage control terminology; that is, basic damage control knowledge, damage control material readiness, and damage control situation management. The CAMIS techniques, methodology, and technology provide a solid vehicle for IDCTT's implementation and a key for FDI development.

C. THE BATTLE DAMAGE ESTIMATOR (BDE)

1. BDE METHOD

The CAMIS format for delivering IDCTT will not be able to completely satisfy TSS requirements if the data being presented do not mirror reality. The BDE is the cornerstone of coordinated IDCTT training because it is able to provide accurate ship damage data that can be used to support the development of meaningful and realistic integrated training scenarios. The BDE is a personal computer-based software program that is able to show the damage caused by weapon effects such as fire, flooding, "frag", shock, blast, and hull whipping. The software is able to provide information on the impact of these weapons on the ship's structure, equipment, systems, and personnel. (Budai, 1992 and McLean, 1992).

The BDE mathematically models the effect of various non-nuclear weapons on surface ships. Damage is calculated to determine the probable degradation of or effects on a ship's seaworthiness, engineering systems, and combat systems. System out-of-action probabilities are obtained by using a Monte Carlo procedure.

> As an example, suppose a 5 hit attack is being evaluated, 5 random hit points (conforming to the specified hit distribution, aim point, etc.) are selected and the components inactivated are cumulatively determined after each hit. This procedure is repeated, using a new set of 5 random hit points each time, until a statistically significant number of trials have been evaluated. Out-of-action probabilities are then determined for each system as the ratio of the number of trials in which the system was inactivated to the total number of trials.
> Vulnerability evaluations can be made for both underwater and air trajectory weapon attacks, but each weapon type and attack direction must be considered separately. Warheads may be contact, delay or proximity fuzed. The computer program can also handle forward facing shaped charge warheads. The approach trajectory for air delivered weapons may be at any elevation angle and at any azimuth. Once the elevation angle is selected, only the azimuth may be varied within the Monte Carlo simulation.

The approach trajectory for underwater weapons must be parallel to and below the waterline. (TSSEIP, p. 3-14)

The target ship is described two ways; in terms of the geometric configurations of the decks, bulkheads, outer hull, and in terms of vital components which are organized into major systems. The configuration is defined by deck and compartment locations. Vital components, such as turbines, generators, and pumps are described in terms of bounding coordinates and shape. Major systems are defined as series and/or parallel combinations of subsystems and vital components (TSSEIP, p. 3-14).

Damage to compartments and vital components is calculated through a set of damage algorithms that evaluate the effect of air bursts, underwater bursts, and internal explosions. After each hit, the BDE calculations account for compartments breached by blast, compartments flooded, as well as the inactivated vital components, and major and minor systems. The data on damage are used to determine overall personnel and system kill probabilities.

2. BDE APPLICATION

The TSS concept was first given a limited test onboard USS PRINCETON[9] during her Refresher Training (REFTRA)[10] in

[9] Ironically, this first TSS drill simulated damage that was the exact casualty experienced by PRINCETON during the Persian Gulf War.

March 1990. A simple tactical scenario culminating with BDE predicted damage was conducted during her Major Conflagration Drill (Mass Conflag)[11]. Lessons learned from this exercise were utilized in planning for a full test of the TSS concept on USS ARKANSAS in April 1990. Detailed preparation for the test on USS ARKANSAS included 27 runs of the BDE to provide a range of possible hits. Review of the Ship's Damage Control Plates and ship checks of actual equipment locations confirmed the probable accuracy of projected damage (TSSEIP, p. iv).

By November 1990, Fleet Training Group, San Diego had conducted five TSS exercises and concluded that the BDE

> . . . provides a logical estimation of probable damage based upon engineering design factors. It provides likely and logical scenarios with which ships' crews can practice and test their knowledge of systems and skills in restoration (COMFLETRAGRU San Diego, CA Naval Message 071545Z Dec 90, Subject: Total Ship Survivability (TSS) SITREP).

Currently, Afloat Training Organizations (ATOs), which were formerly the Fleet Training Groups (FTGs), conduct TSS training during REFTRA. The BDE based scenarios, like those used on PRINCETON, ARKANSAS and in subsequent REFTRAs, highlighted several aspects of a ship's procedures,

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[10] The Afloat Training Organization, formally the Fleet Training Group is responsible for training and evaluating ships in all of their warfare areas. Each ship is scheduled for this training and evaluation approximately once every 18 months. This training and evaluation period is called refresher training (REFTRA).

[11] A drill in which the crew has to combat two or more catastrophic casualties. e.g., A missile and a mine hit.

instructions, and training that failed to fully support the TSS concept. The TSS exercises exposed a lack of an effective method to display the status of the ship to the Commanding Officer, at his battle station in the Combat Information Center or even during normal operating conditions (COMFLETRAGRU San Diego, CA Naval Message 071545Z Dec 90, Subject: Total Ship Survivability (TSS) SITREP).

Internally-produced instructions and bills like the combat systems doctrine, battle orders, restricted maneuvering doctrine, and the Commanding Officer's standing orders[12] and fleet generated instructions such as Engineering Operational Sequencing System (EOSS) and Combat Systems Operational Sequencing System (CSOSS) did not mutually support the ships tactical requirements. An example of contradictory doctrine occurred when engineering watchstanders, using EOSS, stripped a switchboard by removing its electrical load in response to a generator fire while combat systems watchstanders were tracking an inbound air raid. The engineering action resulted in a loss of power to combat systems equipment, which precluded defending against the inbound raid. (COMFLETRAGRU San Diego, CA Naval Message 222220Z Aug 90, Subject: Total Ship Survivability (TSS) SITREP). Stripping a switchboard affected by fire is mandated engineering practice during normal conditions. TSS demonstrated the need for an

[12] These instructions provide the crew with specific duties and responsibilities during special evolutions.

integrated prioritization of the ship's functions to avoid the possibility of one department's actions obviating the function of another during periods of crisis.

There were four additional shortcomings associated with internally-generated instructions. They were:

- The configuration of ship's systems during specified conditions of readiness were not standardized, preventing flexible responses to casualties. (COMFLETRAGRU San Diego, CA Naval Message 111630Z Mar 91, Subject: Total Ship Survivability (TSS) SITREP);

- Many ships failed to prescribed policies or delineated equipment restoration priorities necessary for system reconfiguration in the event the ship received damage. (COMFLETRAGRU San Diego, CA Naval Message 222220 Aug 90, Subject: Total Ship Survivability (TSS) SITREP);

- There was no procedural contingency plan to establish or maintain an alternative source of communications between damage control and engineering personnel with command and combat systems personnel. Not having a secondary or tertiary means of establishing internal communications prevented timely command and control and hampered the restoration of vital equipment during TSS drills (COMFLETRAGRU San Diego, CA Naval Message 111630Z Mar 91, Subject: Total Ship Survivability (TSS) SITREP); and

- The lack of training on the interplay of combat and engineering systems, combined with the weak damage control abilities of combat system personnel, delayed the restoration of weapon systems.

After exposing a ship's weaknesses, the ATO provides guidance from lessons learned that help streamline the internal information coordination necessary to make decisions that satisfy TSS. TSS training has already demonstrated improvements in (1) ship post-hit fighting capability, (2) crew confidence, and (3) applications for future system designs (TSSEIP, p. iv).

The ATO's TSS training is generally considered top quality training, but current ATO availability constraints afford a ship this expert attention only once every 18 months. Steps need to be taken to provide training that would maintain ship's proficiency throughout its 18 month cycle[13]. Three things are needed to make the training more available. First, fleet training organizations need to train shipboard personnel as "in-house" experts who can develop and implement realistic TSS training. Second, local interim training for these key decision makers is needed to maintain their peak proficiency. Third, and the area of focus for this thesis, the decision making of these key personnel in the TSS environment (specifically the DCA) can be evaluated and enhanced by applying new training technology to BDE based IDCTT scenarios.

D. DAMAGE CONTROL COMPONENTS

The environment, delivery system, and source of accurate damage information have been identified for IDCTT. This section addresses the essence of IDCTT by defining (1) damage control objectives, (2) damage control tasks and (3) damage control measures of performance.

[13] Surface ships have 18 month deployment cycles where they spends 12 months preparing for each six month deployment. During the preparation phase, a ship is continually involved in training and evaluation on its warfare areas.

1. DAMAGE CONTROL OBJECTIVES

This section will define the three objectives of damage control as the logical first step in developing DCA MOPs.

a. PREVENTION

The purpose of prevention is to take all practicable preliminary measures to maintain ship's watertight and fumetight integrity, maintain reserve buoyancy and stability, remove fire hazards and upkeep, and distribute emergency equipment before damage occurs (NSTM chap 079 vol 2, p. A-7).

b. MINIMIZATION

Damage control attempts to minimize and localize damage by taking measures to control flooding, preserve stability and buoyancy, combating fires and administer first aid treatment to personnel (NSTM chap 079 vol 2, p. A-7).

c. RESTORATION

The goal of restoration is to, as quickly as possible, conduct emergency repairs after being damaged. Some actions that help restore a ship include supplying casualty power to vital systems, regaining a safe margin of stability and buoyancy, replacing essential structures, and by manning essential equipment (NSTM chap 079 vol 2, p. A-7).

2. DAMAGE CONTROL TASKS

There are seven general DC tasks that satisfy the DC objectives of which six are applicable to IDCTT. Successfully performing these tasks constitutes a minimum level of performance. These tasks entail:

- Preserving stability and watertight integrity (buoyancy),
- Preserving fume and airtight integrity,
- Maintaining the operational capability of vital systems,
- Preventing, isolating, fighting, extinguishing, and removing the effects of fire and explosion,
- Preventing personnel casualties and facilitating care of the wounded, and
- Making rapid repairs to structure and equipment (Information flow and Decision-Making in the DC Organization for DDG-51 Class ships, 1989, p. 2).

3. DAMAGE CONTROL MOPs

The Navy Personnel Research and Development Center (NPRDC) is one of the principal organizations responsible for the development of IDCTT. Part of their tasking required them to clarify the relationship between MOEs and MOPs for IDCTT.

> The old MOE for a ship in combat during WWII would have been to get the ship up and running after damage. The new philosophy again looks at the response times of the new weapons systems and asks how fast can the ship be back up and fighting (after damage is sustained). The MOPs should have a positive effect on the MOE. The better the scores of the MOPs the less time it should take to restore the ship's systems (Robinson, 1992).

NPRDC, with the help of this research, then determined the general criterion for determining DCA performance. These

DCA skills were targeted to be improved through training conducted in a BDE-based interactive multimedia scenario. As with CAMIS, the scenario (problem space) has paths to save the ship, paths that allow the ship to fight even though it will eventually be lost and paths that quickly destroy the ship.

Since each individual enters training with a different level of competency, NPRDC envisions the creation of scenarios that have several levels of difficulty (1-10) to appropriately challenge the abilities of the trainee. A level 1 scenario, which may represent only one hit, would be relatively mild, while higher level scenarios would grow in severity and complexity. In all cases however, there are specific tasks that the DCA must perform, each being initiated at a decision node. At each of these decision nodes, the DCA can be evaluated using the following generic NPRDC MOPs:

1. Recognition of the problem(s)
2. Retrieval of necessary information
3. Interpretation of information/data from several sources (recall how new information will be interpreted - new information will be compared to old information for corroboration) data options:
   a. Act on data,
   b. Ignore data,
   c. Call for more data,
4. Decisions:
   a. Levels of correctness:
      (1). Right actions (ideal path/shortest time),
      (2). Common mistakes,
      (3). Wrong actions,
   b. Condition of the decision maker:
      (1). Normal conditions,
      (2). Conditions of stress,
5. Communication of problem to other parties (Robinson, 1992),
6. Timeliness of decisions, and
7. Awareness and management of the total situation.

The seven areas addressed by NPRDC's MOPs focus on the cognitive processes leading up to a decision and the associated decision. This concept was critical to the development of the FDI because the MOPs determined the essence of what the FDI was designed to capture. Decision making is the most critical responsibility of a DCA managing a damage control problem and the most difficult to teach. The NPRDC MOPs provide the formula for reducing DCA decision making down to its core components. Evaluating the individual components facilitates easier identification of decision making failure points and re-training those specific weaknesses.

E. SUMMARY

CNO mandates level IV ship survivability management training to prepare ships' decision makers for the complex environment of TSS. The procedures the DCAs are expected to follow, the equipment and the skills required, and the conditions of the job provide sufficient task-descriptive data to allow the design and implementation of a program that satisfies this CNO requirement.

IDCTT's design and objectives should establish an acceptable level of job performance. Performance standards for specific tasks serve as a baseline for designing training and can serve as an indication of performance enhancement as a function of that training (Fleishman, p. 8). IDCTT's objective is to develop an interactive system that will train

DCA's to make correct decisions during mass conflagration and TSS situations (McLean, 1992). IDCTT is a research and development program under the auspices of the Naval Sea Systems Command (NAVSEA). The Navy Personnel Research and Development Center (NPRDC), the Center for Interactive Media (CIM) in Medicine at the Uniformed Services University of the Health Sciences, Systems Integration & Research Inc. (SIR) and the present thesis are all part of a programmatically integrated IDCTT effort.

III. IDCTT PROGRAM COMPONENTS

The previous chapters reviewed the concepts, programs, and methodologies that will be incorporated into IDCTT generally and the FDI specifically. This chapter dissects the unique components of IDCTT by (a) reviewing the pilot TSS scenario, (b) explaining the basic computer programming principles associated with the decision making logic, and (c) describing the development of the program's measure of decision making proficiency - the Fuller Decision Index.

A. IDCTT SCENARIO

> . . . IDCTT is developing a BDE-based TSS scenario for an ICW damage control central trainer in which a DCA is moved from situation to situation based on the quality of his decisions. Scenarios will be created to challenge the DCA's ability to manage a catastrophic DC problem. IDCTT training will be designed to foster integrated TSS analysis, which necessitates the use of the higher level cognitive skills of synthesis, evaluation, and application among others. The ICW presentation will also introduce stress components such as noise, failure, confusion, time limitations and high volumes of situational data (Ulozas, 1992).

1. SCENARIO BACKGROUND

The IDCTT scenario design emphasizes important damage control fundamentals that will be referred to as damage control "teaching points." IDCTT interactive video training will require the DCA to evaluate and re-evaluate simultaneously occurring, dynamic situations to determine the best course of action. As the scenario progresses, the number and complexity of the situations the DCA faces will increase the level of workload and the difficulty of making sound or intelligent decisions.

> This is accomplished by controlled damage hits, each necessitating different damage control actions on the DCA, with the ramifications of non-action or inappropriate action being highly penalizing to the ultimate demise of the ship (Draft, November 9, 1992)[14].

As of January 15, 1993, the first BDE-based TSS scenario is cycling through a review of its first draft. This draft establishes the complete overall scenario and Damage/Actions, tailored specifically to the USS JOHN PAUL JONES (DDG-53). The following criteria are being used in the development of the Scenario:

- A total scenario real time period of 20-25 minutes is considered the maximum for this initial demonstration model;
- The first model to be produced is principally meant to demonstrate, though as completely as possible, the concept of the training tool, rather than be an attempt at the final training product;
- As many "Teaching Points" as possible have been included, with sufficient viability, within time and complexity constraints. Certain DC actions, and expected damage, have intentionally been excluded due to time constraints;

[14] "Draft" refers to the DCA Interactive Training Model Development Package - Draft I as written by SIR. "Review Draft" refers to the second iteration, which is the first revised draft of the same package. The members of the implementation planning group provided comments and suggestions that were incorporated into the "Review Draft."

- It is emphasized that this Model is intended to train the DCA, not the DC organization at large; and
- The format has been structured to allow for easy development of each event as detailed definition continues to support production of the Model (Review Draft).

2. SCENARIO DESCRIPTION

The USS JOHN PAUL JONES (DDG-53) will be steaming in the Persian Gulf when she receives indications of hostile aircraft in the area. The ship is also in a known mine threat area. The Commanding Officer orders General Quarters (GQ)[15].

The DCA is in his stateroom when GQ is sounded. While enroute to Damage Control Central, the DCA will be exposed to pre-damage situations. A mine explodes on the aft starboard side of the ship beneath the waterline at frame 400. Enemy aircraft launch an Exocet type missile which impacts the ship at frame 200 on the port side superstructure and explodes. Personnel, system, and structural casualties are investigated and reported.

Principally, the mine hit causes a fire, equipment damage in the aft generator room, and floods two aft storerooms. The missile hit causes fire, personnel, and equipment damage. The DCA has to coordinate the damage control actions of the repair parties.

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[15] General Quarters is the highest state of readiness of a ship. All repair lockers are manned and fully equipped to combat casualties.

The firemain[16] and chilled water systems are ruptured in both hits, requiring isolation and restoration decisions. Personnel routing, equipment deficiencies, stability concerns, out of control situations, and other incidents add complexity to the Scenario.

The Scenario concludes successfully if the DCA makes reasonable decisions appropriate to the damage incurred by the ship. A successful path includes both minor and major "mistakes" or DCA decisions/action pit-falls which would affect the outcome.

In keeping with the TSS concept and since the ship is clearly targeted and vulnerable to subsequent attacks, the over-riding concern of the command will be the amount of degradation to and the restoration of the Combat Systems (Review Draft).

B. IDCTT PROGRAM LOGIC

Although the IDCTT scenario authors are painstakingly establishing a realistic expert path through the scenario, the complexity of the scenario and the almost limitless permutations associated with the DCA's actions or inactions make it nearly impossible to script every conceivable real-time situation. This is partly because the scenario is

[16] Seawater is provided to the ship in the firemain system. This seawater is the ship's primary firefighting agent as well as a medium used to cool equipment and auxiliary machinery (NWP 62-1 (Rev. C) p. 1-10).

written using a linear concept, where actions take place sequentially. The difficulties of accurately tracking the multitude of simultaneously occurring system reactions to independently initiated catastrophic events, like a mine or missile hit, are alleviated by the BDE. The evaluation problem arises when trying to track the status of the ship's systems as they respond to the DCA's actions or inactions.

CAMIS programmers working on the medical triage problem circumvented this problem by using the computer to track the status of all bodily systems at once. The computer also records every user input. A matrix with a predetermined set of systems' conditions allows continuous tracking of each system and the cumulative status of the patient. The "matrix logic" "knows" which supporting systems or sub-system components need to be fully operational for system "x" (say for IDCTT, the firemain) to be at 100 percent. The matrix logic will be programmed to understand the ship's "physiological" or functional reactions to system "x" being degraded based on the BDE's fire spread algorithms, system's deactivation diagrams, and the "teaching points." Given the ramifications of system "x's" degradation, restoration becomes a stressful and time critical situation that decision makers must manage (Allely, 1993).

C. IDCTT EVALUATION: THE FULLER DECISION INDEX

IDCTT is being developed to improve the decisions made by DCAs operating in a TSS environment by incorporating the CAMIS format of interactive courseware, information from the Battle Damage Estimator, and damage control objectives, tasks, and measures of performance. IDCTT is also establishing a taxonomy of human task performance that provides the foundation for a new evaluation technique - The Fuller Decision Index (FDI).

The FDI, the product of this thesis, is a decision making quality measurement system that was developed with the goal of objectively and statistically deriving expert performance standards for IDCTT. The first objective performance standards derived by the FDI will be obtained using the decision making performance of a sampling of damage control experts participating in the pilot IDCTT technology demonstrations. This expert level of performance will be the standard that IDCTT will use to train DCAs. FDI evaluation will compare individual DCA performance to the mean number of decisions made in the scenario, mean information, decision quality, and scores, and the mean time it took the experts to successfully complete the scenario.

> By using interactive trainers to compare the preferred decisions of the experts to the students, and evaluating why what the student did was not as good, we can teach the proper thought process for DCAs. IDCTT will stress the fundamentals while also teaching DCAs to anticipate future situations without being subjected to simple static numeric tests to gauge their knowledge (Miller, 1992).

The FDI is an evaluation tool that quantifies decision making quality by examining both the information known before a decision is made and the results of that decision. One reason the research for and development of the product of this thesis, the FDI, is unique is that this index is being created in concert with another program's development - IDCTT. This thesis, a front-end or formative analysis, focuses on quantifying the expected added training value of using IDCTT to improve the decision making of DCAs by examining decision theory, other scenario driven decision making programs, and the benefits of using ICW.

1. FDI DEVELOPMENT METHODOLOGY

The most important guideline used for developing the FDI was the goal that the system should only measure the DCA's performance as a function of the impact each decision has on the ship's overall status[17]. Reviewing theories of information processing and decision making was a critical step in creating a tool that quantifies the results of the decision making process, especially under conditions of high arousal or workload. The design of the FDI was also derived by examining the strengths and weaknesses of the other programs reviewed in this report. The FDI was created to meet the following objectives:

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[17] Many of the concepts used in creating the FDI draw on techniques described by Capt. Jim Miller, USN Ret. during an interview December 10, 1992.

- Only evaluate decisions as they relate to the scenario's specific teaching points. This keeps tight focus on the question, "What are we trying to teach?"
- Evaluate the pre-hit and post-hit activities separately even though some pre-hit items may impact post-hit performance.
- Determine relative priorities for teaching points. This hierarchy should be adhered to for any given array of simultaneously occurring events.
- Establish an "expert decision path." This path will be used as a benchmark when determining expert performance. Expert performance will then be the standard by which a DCA will be evaluated.
- Establish plausible alternate paths (matrix logic).
- Evaluate the "goodness" of each decision by dividing decision making into two parts - information used and actual decision results. This method supports the underlying, applicable MOPs (problem recognition, information retrieval, interpretation of data, decision path, communications, timeliness and overall situational awareness).
- Quantify the components of the two parts of decision making. Ensure all possible conditions of information and decision outcome are accounted for.

Keeping these objectives in mind, the Fuller Decision Index (FDI) is a model that uses (a) damage control teaching points and (b) decision evaluation variables to measure the DCA's ability to translate IDCTT scenario information into a comprehensive picture, prioritize the casualties and make decisions that will return the ship to the highest possible level of readiness.

2. TEACHING POINTS

The use of specific IDCTT teaching points and matrix logic make it possible for the FDI to measure the impact the DCA has on the ship's ability to prepare for and recover from damage. The IDCTT scenario is divided into two distinct phases, (1) a pre-hit phase and (2) a post hit phase, which encompasses all situations that arise after the first weapon impacts the ship, including other hits on the ship.

a. *PRE-HIT*

The actions required of the DCA in the first section of the IDCTT scenario are less dynamic than those required for the chaotic post-hit phase because there is less information uncertainty and the events present themselves in a naturally occurring order. The priorities given to specific events by the FDI delineate the relative importance of each event. The pre-hit teaching points, given in their order of appearance in the scenario are (1) following formal routes to General Quarters (GQ) stations, (2) verify the proper setting of material condition Zebra, (3) ensure correct battle dress, (4) verify proper manned and ready reports, (5) confirm proper Zebra reports (6), manage Damage Control Central administration, and (7) remove missile hazards from DC Central. The IDCTT scenario pre-hit teaching points are discussed below.

- **Take Formal Routes to General Quarters.** The U.S. Navy has established specific traffic patterns for personnel when a ship goes to GQ as an effective method for alleviating confusion and congestion. The DCA will have the option to use the standard "up starboard forward, down port aft" route or a different route to his GQ station in DC Central. (Priority 7 of 7)[18]

- **Follow Proper Setting of Material Condition Zebra.** The DCA will have the opportunity to correct personnel improperly setting material condition Zebra enroute to and while in DC Central. (Priority 6 of 7)

- **Ensure Correct Battle Dress.** The DCA will have the opportunity to correct personnel in DC Central who improperly don battle dress. (Priority 4 of 7)

- **Verify Proper Manned and Ready Reports.** The DCA will ensure all stations expeditiously report that they are manned and ready for action. (Priority 2 of 7)

- **Confirm Proper Zebra Reports.** The DCA will ensure that all stations report the proper setting of material condition Zebra, verifying that the reports concur with remote censors and that fittings that are known to be open are or out of commission are properly reported by the stations responsible for their closure. (Priority 1 of 7)

- **Manage Damage Control Central Administration.** The DCA will manage the actions of DC Central, ensuring that the information necessary for all the administrative functions are ready for use. (Priority 3 of 7)

- **Remove Missile Hazards.** The DCA will ensure that all unsecured objects are properly stowed or anchored down to avoid becoming missile hazards. (Priority 5 of 7)

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[18] Priority 7 of 7 is the lowest priority in the pre-hit teaching points. This section is awarded a numeric priority because the tasks for going to GQ are standardized. The post-hit teaching points can only have relative priorities because their associated actions must be taken in response casualties as they occur.

b. POST-HIT

Most of the IDCTT scenario concentrates on the decisions of the DCA after the ship has been damaged. The DCA will be forced to deal with several catastrophic situations that require him/her to absorb the information flowing into DC Central and manage the damage control situation using Total Ship Survivability (TSS) philosophies to prioritize his/her decisions. The post-hit teaching points are discussed below in their relative priority as determined by this research.

- **Check Communication.** The DCA will ensure that constant communications are maintained between DC Central and all reporting stations.

- **Inform Chain of Command.** As a function of maintaining communications with all reporting stations, the DCA will ensure that the chain of command, specifically the commanding officer in CIC and the executive officer on the bridge, are appraised of the damage control situation its potential ramifications.

- **Restore Communications.** If communications are lost for any reason, the DCA will ensure that all measures are taken to restore communications.

- **Locate Damage.** The DCA is responsible for ensuring the lockers investigate for, locate and report all damage to DC Central.

- **Prioritize Casualties.** After considering all available information, the DCA will prioritize damage in accordance with TSS principals.

- **Coordinate Teams.** The DCA will coordinate the actions of the repair parties to facilitate combating the damage according to its relative priority.

- **Isolate Damage.** The DCA will approve measures to prevent the further spread of fire, flooding and smoke.

- **Isolate Explosive Hazards.** The DCA will order the isolation of hazardous material near a fire because they are critical areas that require immediate attention to prevent catastrophic secondary explosions from further endangering the survivability of the ship.

- **Restore Firemain.** The DCA will monitor the firemain and take all necessary action to restore it if there is a degradation in the system. The firemain is the DCA's principal tool for combating casualties.

- **Restore Vital System.** The DCA will take actions necessary to restore the ship's vital mechanical systems. TSS principals determine the relative priority for initiating system restoration.

- **Calculate Stability.** The DCA will validate the accuracy of stability calculations, and inform the command of the actions necessary to maintain the stability of the ship.

- **Manage Damage Control Central.** The DCA will manage the actions of DC Central, ensuring that information is being accurately gathered and passed and that all the administrative actions are being carried out properly.

- **Provide Battle Routes.** When required, the DCA will provide personnel with routes for safe passage for one destination to another.

- **Order Casualty Power.** When required, the DCA will order the rigging of casualty power. The DCA will also determine and assign the source and destination for casualty power.

- **Manage Personnel Casualties and Evacuations.** The DCA will support the aid of personnel casualties by coordinating information on, determining safe routes for and managing the safe movement of all ship's personnel casualties.

3. DECISION EVALUATION VARIABLES

The equation for the Fuller Decision Index is shown below. It is comprised of two critical components which mathematically yield a maximum score of one point per decision. The first component, which is given a weight of 40 percent, captures the gathering and processing of information, which constitutes the DCA's pre-decision information base. The second component, which is given a weight of 60 percent, captures the correctness and timeliness of a DCA's decision, which constitutes the impact the decision had upon the intended problem.

$$((\frac{INFORMATION}{IGT}).4)+((\frac{DECISION}{DGT}).6)\leq 1$$

The 40/60 split between information base and decision outcome is a function of the relative importance of the of the two components which, together constitute damage control decision making. The most important consideration when evaluating DCA performance is the outcome of each particular decision. Positive results, which are absolutely essential for effective damage control, receive a greater weight, even though there are many historical examples in which the right decisions were made for the wrong reasons. The FDI, which assumes that better decisions are made when founded on more accurate information, compensates for the likelihood of a correct decision for the wrong reason by weighting the importance of the pre-decision information at 40 percent. The two global variables in the original formulation ("Information" and "Decision") have discrete components. These components and their respective weights are discussed below.

a. Measuring the DCA's Pre-decision Information

The DCA has several sources of information in the pilot IDCTT scenario. These sources occasionally pass inaccurate, ambiguous, or conflicting information. The quality of a DCA's pre-decision information base will be inferred or "known" from recording the information the DCA acknowledged receiving or subsequently transmitted to interested parties during the interactive training session. If the correct information was known, but a poor decision was made, it is assumed that the DCA failed to properly incorporate that information into the decision making process. The four variables that compose "Information" and measure the quality of the DCA's pre-decision information are listed, weighted, and defined below.

- **Information Ground Truth (IGT) = 1**
  The Battle Damage Estimator's (BDE) predicted weapons effect on the ship.

- **Information Available, Not Sought (IANS) =.2**
  Relevant or critical situation information was available but was not known. This includes not clarifying ambiguous or conflicting information.

- **Information Known (IK) =.7**
  Relevant peripheral information on a particular situation is known.

- **Critical Information Known (CIK) = 1**
  Exact location of a casualty or specific cause of system degradation is known.

The Information Ground Truth (IGT) variable will always be the denominator in the information component of the equation, using only one of the three other information variables as the numerator for any particular decision. The value of the denominator will always equal one, because it reflects the highest level of information available; that is, "ground truth." The weightings associated with the information variables in the numerator reflect this writer's best determination of their relative importance with respect to ground truth.

b. Measuring the Quality of the DCA's Decision

The IDCTT scenario is a combination of independently initiated events that can only be successfully resolved by the DCA's correct actions. The DCA's actions exercise no influence or control over the independent initiation of an IDCTT scenario situation, like a mine or missile hit. However, all of the DCA's decisions or indecisions will have a positive, negative, or neutral effect on the dynamic status of ship and its systems. The six variables that compose "Decision" and measure the quality of the outcome resulting from each DCA decision are listed, weighted and defined below.

- **Decision Ground Truth (DGT)=1**
  This is the subjectively derived determination of the best decision to successfully resolve a situation. This variable will be used as an initial standard for statistically determining a best objectively derived decision in future studies.

- **No Action Initiated (NAI)=0**
  No corrective action was taken when action was appropriate for the given situation.

- **Action Initiated (AI)=.25**
  A decision that caused some change in an independent string of events initiated by the scenario, but the decision has either neutral or negative effects because

it does not help successfully resolve the situacion. This accounts for all of the possibilities that are not timely, correct or partially correct.

- **Correct Action Initiated (CAI)=.75**
  An action is initiated that has positive impact by improving a situation. It may or may not lead to the successful resolution of a situation.

- **Action Initiated Timely (+T)=.15**
  The value of this variable is only added to CAI if an action is taken in time to successfully resolve a specific situation.

- **Correct Action Initiated Timely (CAIT)=1**
  A correct action was initiated in the most expeditious manner to successfully resolve a situation.

The Decision Ground Truth (DGT) variable will always be the denominator in the decision component of the equation, using only one of the other decision variables as the numerator for each decision. The only exception to this rule is when a correct decision is made in a timely manner; earning an additional bonus of 15 percentage points. The value of the denominator will always equal one, because it reflects the best decision available; that is, "ground truth." The weighting associated with the decision variables in the numerator reflect this writer's best determination of their relative importance with respect to ground truth. The relationship between the decision variables is depicted in Figure 2.

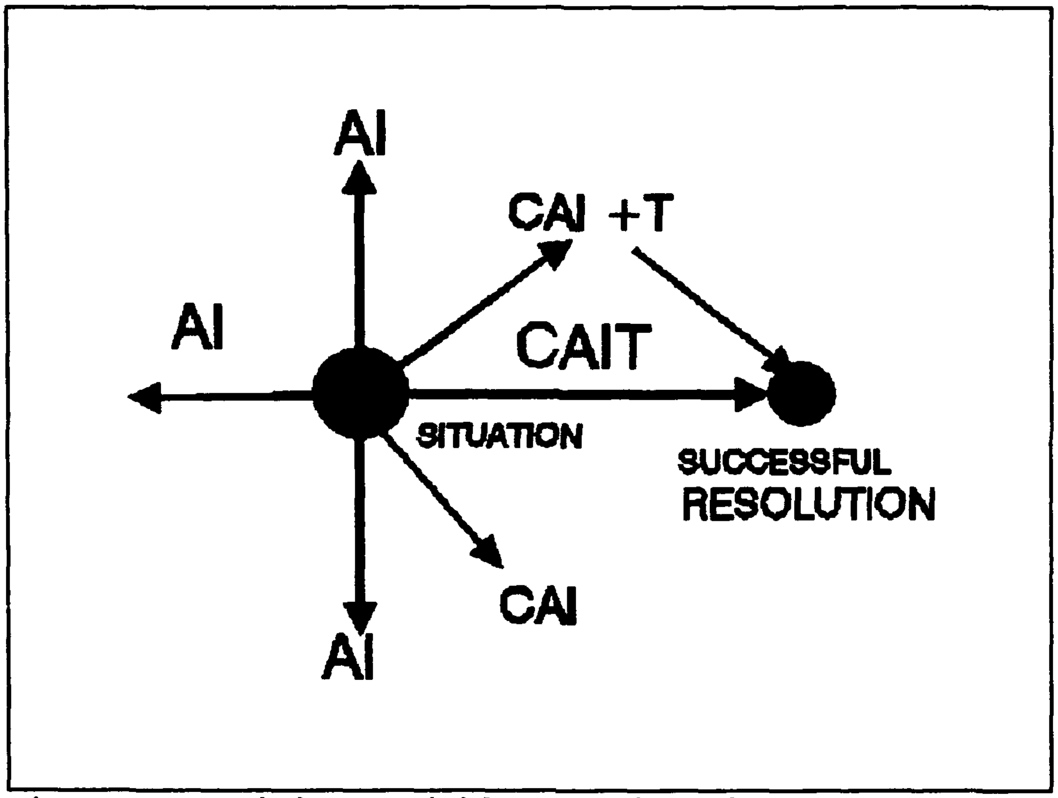

Figure 2 Decision variable relationship

4. FULLER DECISION INDEX SCORING

The maximum score awarded for each decision is one point as depicted in Figure 3. Every time the DCA makes a decision related to a teaching point, the relative quality of that decision will be calculated by cycling through the appropriate decision evaluation variables. The FDI will measure the quality of information used before the DCA made a decision as well as the outcome of the actual decision. The sum of the two components - quality of information and outcome of the decision - is the decision score, which when combined with all the other decision scores creates a raw score. The raw score divided by the total number of decisions, multiplied by 100 equals the DCA's decision quality (DQ) percentage. The

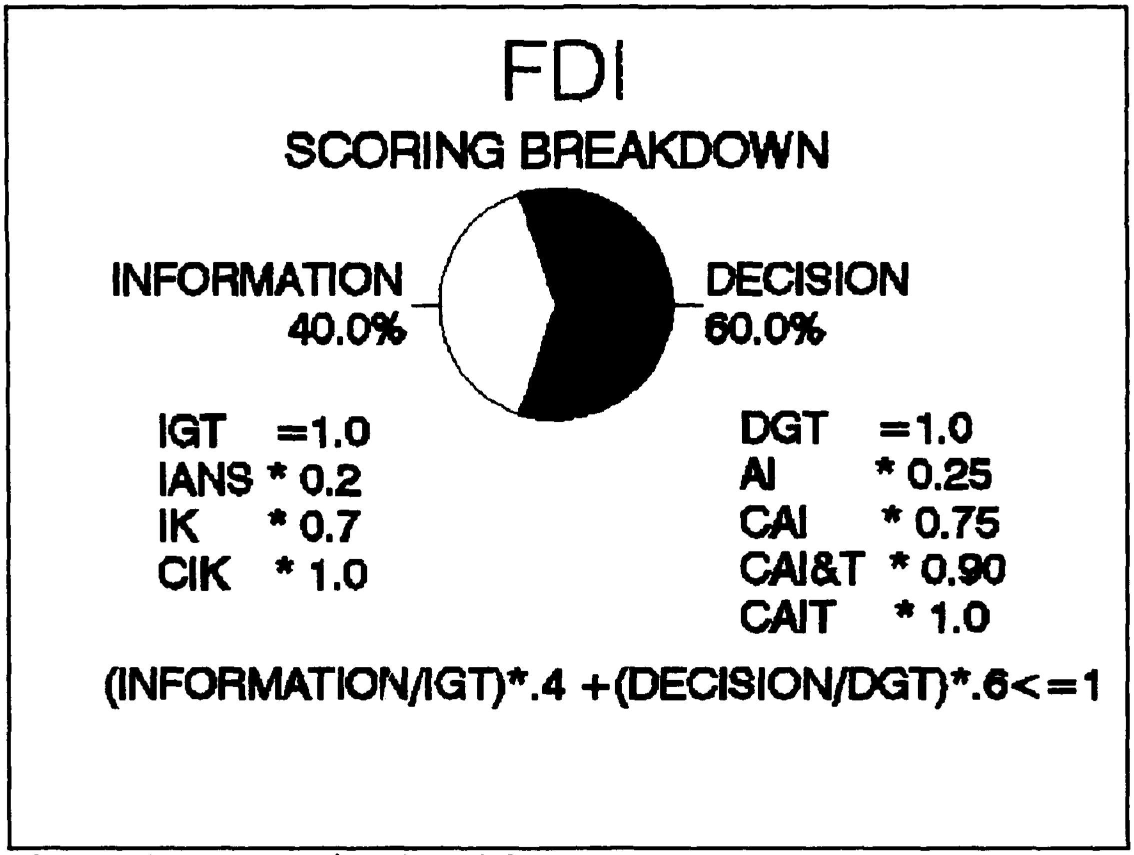

Figure 3 FDI scoring breakdown

decision score can also be analyzed in terms of the percentage of its components by examining the overall quality of DCA information or decision outcomes.

$$100[\sum((\frac{INFORMATION}{IGT}).4)+((\frac{DECISION}{DGT}).6)/\sum DECISIONS]=DQ\%$$

5. PREDICTED FDI FINDINGS

Recall that the IDCTT matrix of conditions, in much the same way CAMIS does, takes a snapshot of the condition of the ship at a specific moment, recording both the time and the change in the ships status as a function of both independently occurring scenario driven events and events caused by the

DCA's decisions. The FDI will capture the information known by the DCA during each of these situations.

Combining the sequential snapshots after each DCA decision transforms information configured in a two dimensional bar graph with each bar representing the DCA's relative information base superimposed over the ground truth status, depicted in Figure 4, into a three dimensional time series representation of the evolution of the DCA's information base which is superimposed over ground truth - a surface - depicted in Figure 5. Along with providing the simple statistics detailing the number of decisions made and time for scenario completion, the evolving surfaces will graphically compare the dynamic evolution of ground truth (BDE predicted ship's status) to the DCA's known information as a function of the outcome of each decision.

The "Beta test" phase of IDCTT will use the FDI data to establish an expert level of performance as a benchmark for future comparison. The FDI will only evaluate decisions dealing with the teaching points, eliminating much of the confusion associated with determining why one matrix condition or surface evolved into another. Focusing the FDI on scenario dependent teaching points also helps to objectively and statistically prove or disprove the hypothesized assumptions used in developing IDCTT. This writer predicts that the

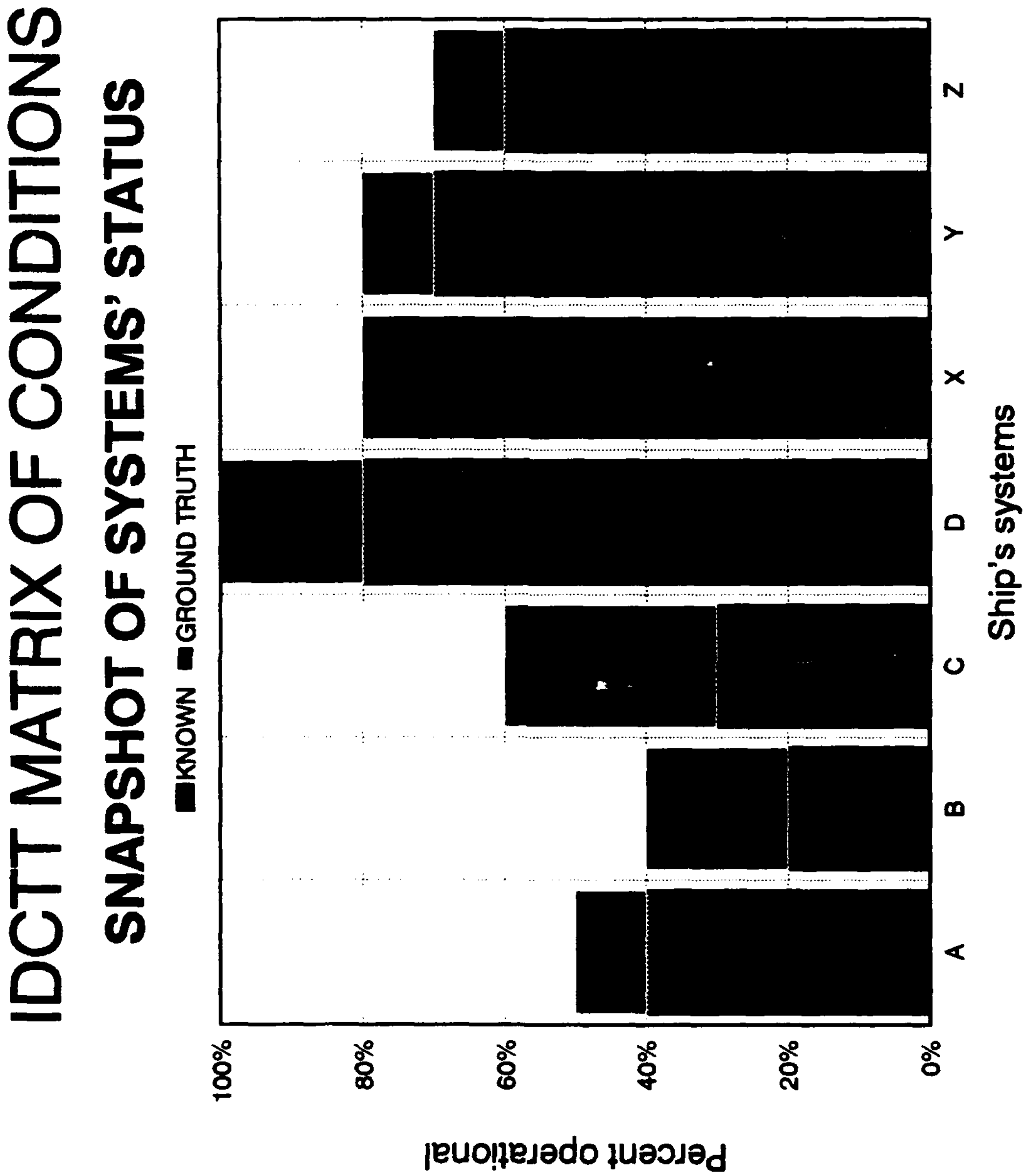

Figure 4. Snap shot of ground truth versus known information

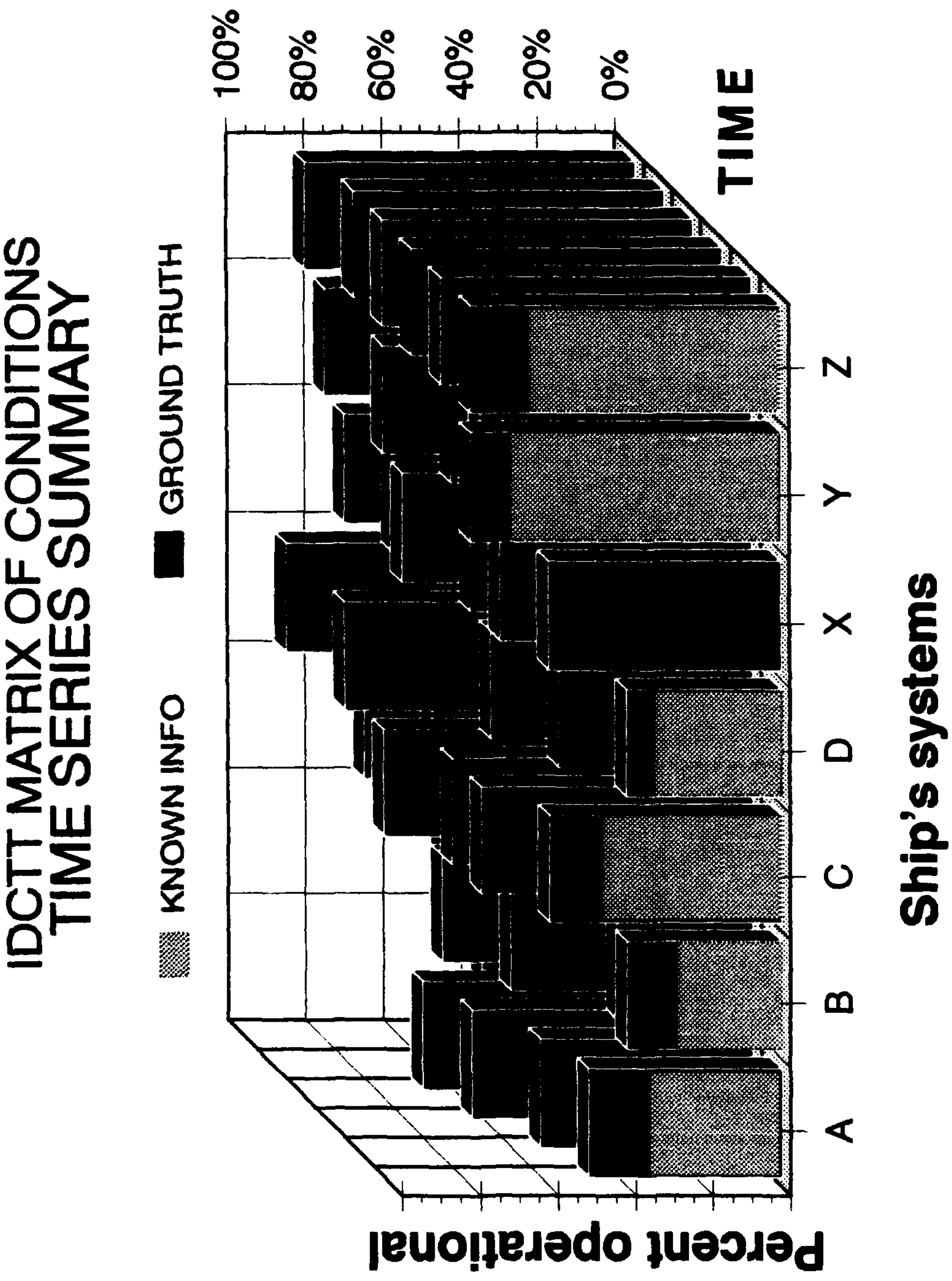

Figure 5. Time series summary of ground truth versus known information

performance of damage control experts will statistically support the assumptions used to develop IDCTT and the FDI. This research derives the following hypotheses on expert decision making performance:

- The priority of subjectively derived teaching points will be validated by the time and frequency experts request information. The earlier they address a teaching point and their greater initial query frequency will correlate to its relative importance;
- Matrix surfaces will reveal an expert path consistent with the teaching points relative priorities;
- The amount of known information and decision quality will be a highly correlated;
- Experts will resolve information ambiguity significantly faster than novices;
- Expert performance will be degraded significantly less than novices as a result of high workload.

Given that the hypotheses generated for expert performance are true, the performance of novice DCA's will be significantly poorer than experts. A major reason for weaker performance in the IDCTT scenario will result from cascading errors as a consequence of being caught in a teaching point "pitfall." Pitfalls are the major or minor repercussions of missing a teaching point. Major pitfalls are much more lethal than minor pitfalls. Hypotheses on the why the novice's performance will be weaker than expert performance are as follows:

- Novice's susceptibility to teaching point pitfalls will be highly correlated to both poor information and high workload;

- Novice's ability to process known information will be degraded as workload increases. Even though the information was gathered, the decisions will still be poor;

- Given the novice's degraded information processing ability, they will access information on the same topic more often and fixate on narrow swath of the problem. This trend will have a different shape from experts surfaces which will indicate attention on several critical items early in the scenario. Novice fixation will hinder the acquisition of known information on other critical situations and will result in activation;

- Fixation will also result in significantly degraded levels of in managing routine, lower priority events.

D. SUMMARY

IDCTT's is a research and development project that is uniquely focused on its goal of demonstrating new training technology to support TSS and the CNO mandated level IV ship survivability management training. The complete integration of fact-based scenario development, advanced programming methodology, and insightful evaluation techniques is innovative, logical, and programmatically sound.

The creators of the IDCTT scenario painstakingly investigated every aspect of the target platform to ensure the highest level of fidelity for the training. The IDCTT programmers, using the CAMIS methodology, solved the problem of creating realistic functional ship responses to both scenario driven and DCA actuated events. The research for and the development of this thesis addressed and incorporated relevant findings from the following topical areas:

- Principles of TSS doctrine,
- Theories on stress and decision making,

- Lessons learned from other research into decision making and their associated programs,
- Personal damage control experience,
- The BDE and pilot IDCTT scenario, and
- The limitations and capabilities of ICW.

The analysis of these six interrelated subjects provided a basis in fact and supposition on which the Fuller Decision Index was developed and can be used to quantitatively justify the impact of an IDCTT application with respect to DCA decision making proficiency.

IV CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The FDI's development precedes the completion of both the IDCTT scenario and the programmed logic for the matrix of shipboard conditions and responses. The research on which the FDI was based is a useful source of information for the organizations involved in IDCTT development. This research addressed the often divisive issues and difficult tasks of defining specific MOEs, MOPs, performance standards, and the impact of stress on individual performance. The FDI was designed to produce quantitative data that can be used to evaluate the actual performance of DCAs in complex TSS situations. The FDI data could ultimately resolve the difficult issues of determining MOEs, MOPs, and performance standards, which previously were simply subjectively derived.

Developing a method to resolve these issues required exploration into the essence of damage control, the TSS situations DCAs are expected to face, and the determination of how DCAs must perform. The task of training individuals to become competent DCAs has become increasing difficult because the TSS doctrine requires that DC training be integrated across all shipboard departments. Evaluating DCA performance, moreover, has also become more complex. The DCA's goal is no longer simply surviving damage, but preparing the crew to perform tasks that restore and reconfigure vital combat systems needed to defend the ship against further hostilities.

The introduction of new ICW training technologies, like IDCTT, will help bridge the training gap between DC requirements and DC capabilities. The FDI, which is an integral part of IDCTT training will, for the first time, provide a quantitative index which measures the specific effect each DCA decision has upon the performance of the DC organization, and by extension, the survival of the ship.

B. RECOMMENDATIONS

Another analysis must be conducted with actual data to determine the psychometric and statistical properties of the FDI; that is, the FDI must demonstrate reliability. A second analysis must be conducted to demonstrate that the FDI can differentiate between levels of decision making proficiency; that is, the FDI must be sensitive enough to reliably capture differences between novice and expert levels of decision making performance. If the FDI is validated, it would provide a means to evaluate emerging training technology and determine its pedagogical efficacy and cost effectiveness. Such a validation would lend credence to the program, creating solid grounds for implementation as an approved training tool for DCAs.

ICW training significantly improves an individual's ability to apply knowledge to difficult tasks. Despite the obvious benefits of ICW, this thesis revealed its obvious shortcomings. ICW provides levels of reality and stress that have not been experienced in damage control training before. The level of emersion into the training, however, can be improved using new technology. The emerging technology of "virtual reality" can improve the fidelity of training environments by simply increasing the level of interactively beyond that which current configurations of ICW can support. Research needs to extend the level of interactively and enhance the level of emersion beyond today's ICW by applying virtual world technology to the DCA training problem.

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